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DISTRIBUTION OF DIFFERENT FRACTIONS OF FE AND THEIR ASSOCIATION WITH SOIL CHEMICAL PROPERTIES IN NORTH SAURASHTRA AGRO-CLIMATIC ZONE OF GUJARAT, INDIA

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ABSTRACT

An attempt has been made in the present investigation to study the Dynamics of iron in the soils belong to North Saurashtra Agro-climatic Zone of Rajkot, Jamnagar, DevbhumiDwarka, Morbi, Surendrnagar, Amreli and Bhavnagar district and interrelations among the fractions from four hundred eighty samples (10 soil samples from each taluka) were collected based on survey of cultivated farmer's fields. The soil samples were analyzed for different fractions of iron *viz.*, Water Soluble, Exchangeable, DTPA Available, Available Total, Total, Residual and Percent Available. On the basis of analyzed data of soil samples collected from different districts cover under North Saurashtra Agro-climatic Zone of Gujarat, it can be concluded that different factions of iron in soils were found between 0.111-4.84, 1.32 to 22.30, 0.498-6.70, 0.075-1.99, 2.05-35.38, 9091-92632, 9084-92622 mg/kg and 0.011-0.081% with mean value 0.642, 2.04, 6.26, 0.101, 9.34, 36143, 36134 mg/kg and 0.026%, respectively for above discused fraction. Soil fertility class based on nutrient index for available iron were calculated. In case of iron about 31 per cent samples were tested as low class (< 5 mg/kg), 59 per cent samples were under medium class (5-10 mg/kg) and 10 per cent samples were under falls in high class (> 10 mg/kg). Based on multiple correlations and regression analysis the prediction model for available Fe was represented, the available Fe was highly significantly positive correlated with towards all fractions. While, in case of soil chemical properties like soil $pH_{2.5}$ and $EC_{2.5}$ were non-significant for different fractions of iron in soils study area, due to at high range of pH (Alkaline) most of iron has less solubility and available. The path co-efficient analysis of available iron fractions with other fractions influenced by the direct positive effect on exchangeable iron ascribed maximum, while other fractionalso direct positive effect on available iron.

Key words : Iron factions, Nutrient index, Correlation, Regression and Path analysis.

Introduction

Micronutrients play important role in Indian agriculture towards sustainable crop production. The importance of micronutrients need to be viewed in food systems context, as their inclusion in balanced fertilization schedule would optimize micronutrient supply and availability in the entire food consumption cycle. Indian soils are generally poor in fertility especially in micronutrients as these have consistently been mined cultivation for a very long time particularly four decade without addition of micronutrient fertilizer resulting in emerging led-increased demand of micronutrients by the high yielding crop cultivars as well as adoption of intensive cropping practices, use of high-analysis fertilizers with low micronutrient content, decreased use of organic manures and crop residues, growing of crops in soils with low micronutrient reserves and other natural and anthropogenic factors adversely affecting phytoavailability of micronutrients aggravated the situation (Takkar and Shukla, 2015).

Micronutrient cations are usually held very strongly by the organic legends; however, those exist in the soils in different pools. Viet (1962) postulated existence of five distinct pools of micronutrient cations in soil *viz*., (i) soil solution or water soluble, (ii) exchangeable, (iii) adsorbed, complexed and chelated, (iv) associated with secondary minerals and as insoluble metal oxides and hydroxides and (v) associated with primary minerals. First three pools exist in a state of dynamic equilibrium and constitute the labile pool from which the plants takeoff micronutrients. Consequently, a number of sequential fraction procedures have been developed for studying the relative abundance of different fractions in the soils and their relative importance in respect of soils for supplying power of micronutrients to the growing crops. The availability of the micronutrients in soil is also affected by the soil properties like pH, EC, content of organic matter, free lime, moisture, soil texture, type of clay, amount of clay and concentrations of interacting ions, *etc*.

Micronutrients has been realized during the past four decades when widespread micronutrient deficiencies were observed in most of the soils in our country, where intensive agriculture is practiced with high analysis fertilizers and high yielding varieties. In Indian soils were found to be revealed that on an average of 36.5, 12.8, 7.1 and 4.2 soils are deficient in Zn, Fe, Mn and Cu, respectively. While, overall percentage deficiency of micronutrients in Gujarat soils was found 36.56, 25.87, 0.46 and0.38 for respective demand of Zn, Fe, Mn and Cu (Shukla *et al*., 2018).

Materials and Methods

Study area

The total geographical area of Saurashtra region is 6.43 million ha representing 32.82 per cent area of Gujarat (19.61 million ha). Of the total geographical area of Saurashtra, 3.95 million hectares (61%) is estimated to be net-sown area, while total geographical area of North Saurashtra Agro-climatic Zone (study area) is 48220 km^2.

Collection of soil samples

The ten surface soil samples were collected from each 48 each talukas of 7 districts belonging in North Saurashtra Agro-climatic Zone of Gujarat during summer season of 2021. On the basis of the information available from the departmental survey, 480 surface (0-20 cm) soil samples were collected from the tagged survey numbers of the North Saurashtra Agro-climatic Zone of Gujarat.

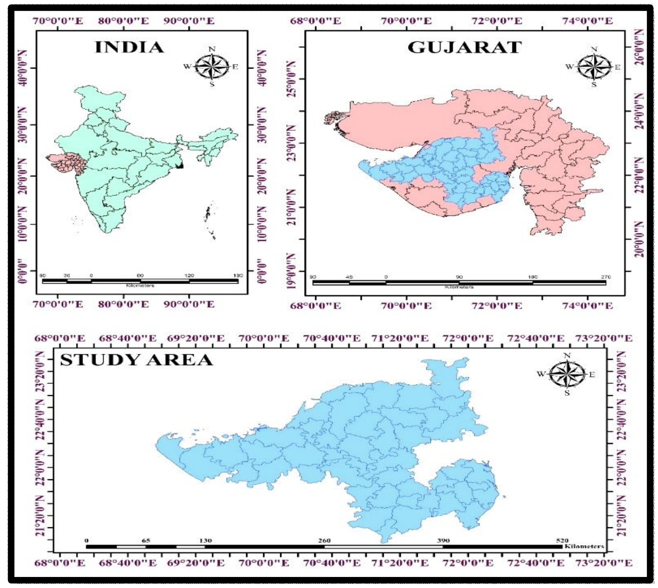

Fig. 1 : Sampling area (Noth Saurashtra Agro-climatic zone).

Soil sample analysis

The prepared soil samples were analysed for determining fractions of Fe, Mn, Zn and Cu by adopting standard methods. Exactly 20 gram processed air-dried soil were weighed accurately into conical flask of 150 ml capacity and to be kept ready for the sequentialfractions analysis of Fe, Mn, Zn and Cu as per procedure described by Jackson (1979) and Viet (1962) as follows:

Water soluble fraction : About 40 ml distilled water add in the conical flask and shake for 2 hours on horizontal (mechanical) shaker. The soil suspension allows to settle down for one hour and supernatant liquid filter through using whatman filter paper number 42 for the analysis of water soluble Fe, Mn, Zn and Cu.

Water soluble fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Exchangeable fraction : Residual soil uses to determine the exchangeable Fe, Mn, Zn and Cu. Take exactly 40 ml of 1 N neutral ammonium acetate add in the same conical flask and shake for 2 hr. The soil suspension allows to settle down as mentioned above and supernatant liquid use for the estimation of above.

Exchangeable fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

DTPA available fraction : Residual soil use for the determination of DTPA available Fe, Mn, Zn and Cu by adding 40 ml DTPA-TEA-$CaCl_2$ (pH 7.3) in the same conical flask and shake for 2 hours. The soil suspension allows to settle down for one hr. The supernatant liquid use for the estimation of above said micronutrients.

DTPA available fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Table 1 : Classification of nutrient index by Parker.

S. no.	Nutrient index class	Value	Interpretation
1.	Low	≤1.67	Low fertility status of area
2.	Medium	1.67-2.33	Medium fertility status of area
3.	High	≥2.33	High fertility status of area

Reducible fraction : Residual soil use for the determination of reducible Fe, Mn, Zn and Cu. Take exactly 40 ml 1 N neutral ammonium acetate containing 0.2% hydro quinon in the same conical flask and shake for one hour, put the suspension at list one hour for separation of soil and supernatant liquid. Use extract for the estimation of above micronutrients.

Reducible fraction (mg/kg) = Net reading (mg/kg) × Dilution factor

Total fraction : Total micronutrients *viz*., Fe, Mn, Zn and Cu to be determined by using HF: HClO4 (5:1). The soil (1.0 g) take in a platinum crucible treated with 2 ml distilled water and 1 ml $HClO_4$ before 5 ml HF to be added. The contents evaporate to dryness. The residue was heated with 1 ml HCl and 5 ml water till it dissolved (discolour). After cooling, the 100 ml volume to be made before filtration and use for the estimation of total elements.

Total fraction (mg/kg) = Net reading (mg/kg) × 100

Residual fraction : Residual Fe, Mn, Zn and Cu were calculated by deducting water soluble + exchangeable + DTPA available + residual (i.e. available total) from total nutrients of Fe, Mn, Zn and Cu.

Residual fraction (mg/kg) = Total fraction - Available total

Percent available fraction : The percent available of Fe, Mn, Zn and Cu were calculated as percent available nutrients in the form of water soluble + exchangeable + DTPA available + reducible (i.e. available total) of the total nutrients content in the respective soils.

$$\textbf{Percent available fraction (\%)} = \frac{\text{Available total} \times 100}{\text{Total fraction}}$$

Available total fraction : Available total was the sum of water soluble, exchangeable, DTPA available and reducible form.

Available total (mg/kg) = Sum of Water soluble + Exchangeable +DTPA available + Reducible form

Nutrient index value was calculated by using following formula given by Parker *et al.* (1951).

$$\text{Nutrient index (NI)} = \frac{(\text{NL x 1}) + (\text{NM x 2}) + (\text{NH x 3})}{\text{Number of total sample}}$$

Where, NL, NM and NH are the number of soil samples falling in low, medium and high categories for nutrient status and are given weightage of 1, 2 and 3, respectively.

Keeping in view above, the soil analysed data were classified as available iron as low, medium and high categories (<5, 5-10, >10 - Low, Medium and High respectivly) as given by Dangarwala *et al.* (1983), Tandon (1995), Patel *et al.* (1999).

Geo-statistics and interpolation delineating maps : Soil samples points marked using GPS were fed into the GIS environment. Values of available iron was tagged with corresponding points and interpolation of maps for each individual parameter was done using IDW technique in Arc GIS 10.0 software. Further, the maps of this buffered zone were generated for available iron (Trehan *et al*., 2008). GIS software was also used to estimate the area falling under different classes of respective chemical parameters (Gorasiya *et al*., 2024).

Results and Discussion

Different fractions of Iron (mg/kg) in soils North Saurashtra Agro-climatic Zone

The overall range of water soluble iron in North Saurashtra Agro-climate was 0.111-4.84 mg/kg with mean value of 0.642 mg/kg. The data revealed that the lowest mean value of water soluble iron (0.344 mg/kg) was obtained from the samples of Jamnagar district and the highest mean value of water soluble iron (0.978 mg/kg) was found in samples of Surendranagar. Similar results was also reported Selvaraj and Basavaraj (2015) for Gangavati taluka of north Karnataka.

Cations held on the clay and organic matter particles in soils can be replaced by other cations; thus, they are exchangeable. The overall range of exchangeable iron in soil was found 0.498-6.70 mg/kg with mean value of 2.04 mg/kg. The data revealed that the lowest mean value of exchangeable iron (1.80 mg/kg) was obtained from the samples of Rajkot district and the highest mean value of 2.58 mg/kg was found in samples of Surendranagar district (Table 2). Naria *et al.* (2008) had similarly found exchangeable iron for cultivated farmers field of Saurashtra region and Selvaraj and Basavaraj (2015) showed exchangeable iron (0.22 to 3.93 mg/kg) in paddy growing soils of Gangavati taluka of north Karnataka.

Table 2 : Range and mean of different fractions of Iron (mg/kg) in soils of different districts of North Saurashtra Agro-climatic Zone.

Name of Talukas	Water Soluble	Exchangeable	DTPA available	Reducible	Avail. Total	Total	Residual	Percent available
Rajkot	0.264-2.71 (0.789)	0.533-5.97 (1.80)	2.66-16.72 (5.51)	0.16-1.74 (0.396)	4.05-25.44 (8.49)	20858-73699 (37072)	20854-73688 (37063)	0.016-0.047 (0.023)
Amreli	0.339-2.99 (0.877)	0.822-5.78 (1.95)	2.92-17.19 (6.84)	0.16-1.54 (0.404)	4.24-27.51 (10.07)	15717-60430 (37097)	15710-60414 (37087)	0.013-0.065 (0.027)
Surendranagar	0.168-4.84 (0.978)	0.489-6.70 (2.58)	1.32-22.30 (7.37)	0.075-1.99 (0.477)	2.05-35.38 (11.40)	13262-69773 (38713)	13258-69755 (38702)	0.013-0.07 (0.029)
Jamnagar	0.151-1.27 (0.344)	1.14-3.22 (1.88)	4.03-10.62 (6.37)	0.178-0.976 (0.402)	5.64-15.62 (9.00)	23158-58966 (38426)	23150-58955 (38417)	0.013-0.033 (0.024)
Devbhumi-Dwarka	0.167-2.74 (0.671)	1.00-4.96 (1.81)	3.61-17.13 (6.29)	0.195-1.52 (0.422)	4.98-26.35 (9.20)	23726-55806 (34973)	23720-55785 (34964)	0.015-0.055 (0.026)
Morbi	0.233-0.820 (0.430)	1.29-4.05 (2.21)	2.8-9.02 (5.10)	0.189-0.564 (0.314)	4.51-14.46 (8.05)	18053-56969 (32707)	18049-56955 (32699)	0.017-0.038 (0.025)
Bhavnagar	0.111-1.17 (0.406)	0.92-4.22 (2.01)	2.95-13.51 (6.34)	0.189-0.866 (0.415)	4.17-19.11 (9.18)	9091-92632 (34013)	9084-92622 (34004)	0.011-0.081 (0.032)
OverallNSAZ	**0.111-4.84 (0.642)**	**0.489-6.70 (2.04)**	**1.32-22.30 (6.26)**	**0.075-1.99 (0.404)**	**2.05-35.38 (9.34)**	**9091-92632 (36143)**	**9084-92622 (36134)**	**0.011-0.081 (0.026)**

The overall range of available iron in the soils was recorded as 1.32-22.30 mg/kg with mean value of 6.26 mg/kg. The data revealed that lowest mean value of available iron (5.10 mg/kg) was recorded from the soils samples of Morbi district and the highest mean value of 7.37 mg/kg was recorded in soils samples of Surendranagar district. The status of DTPA available iron highest noted in Surendranagar district, it is due to most of area under rainfed, less intensive cropping and poor irrigation facility. That's way less iron removal from soils as compared to other districts. Similar findings were also recorded Singh and Athokpam (2018) in soil of Chandel district of Manipur, Thombe *et al.* (2020) also found the status of DTPA extractable iron (2.11 to 9.00 mg/kg) in Shemda and Umtha village of Narkhed tehsil and Durkheda village of Katol tehsil of Nagpur district of Maharastra.

The district wise mean and range value of reducible iron is designated in Table 2. The overall range of reducible iron in soil was 0.075-1.99 mg/kg with mean value of 0.404 mg/kg. The data revealed that lowest mean value (0.314 mg/kg) was obtained from the samples of Morbi district and the highest mean value (0.404 mg/kg) was found in samples of Surendranagar. This finding is in conformity with the findings of earlier work done by Naria *et al.* (2008) for soils of Saurashtra region of Gujarat.

Available total is the sum of water soluble, exchangeable, DTPA available and reducible fraction. Available total iron ranged from 2.05-35.38 mg/kg with a mean value of 9.00 mg/kg. The highest value of available total ironwas recorded in Surendranagar with a mean of 11.40 mg/kg whereas the lowest value of 8.05 mg/kg was recorded in the soil sample collected from Morbi district. The majority part of suendranagar district is under rainfed cultivation due to lack of irrigation facility, hence limited depletion in available total iron content in soil, ultimately the value of available total Fe is high as compared to remaining district of North Saurashtra Agro-climatic Zone. Similar findings were also recorded by Naria *et al.* (2008) for coastal deep and river coastal deep soil group of Saurashtra region of Gujarat.

In the North Saurashtra Agro-climatic region, the overall range of total iron was 9091-92632 mg/kg, with a mean value of 36143 mg/kg. The highest total iron value of 36143 mg/kg was found in Surendranagar, while the lowest of 32707 mg/kg was found in a soil sample collected from Morbi soils. Naria *et al*. (2008) found similar range (10163-31930 mg/kg) of total iron

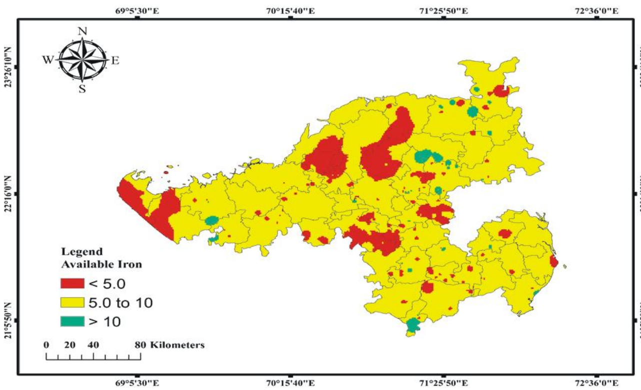

Fig. 2 : Status of available (DTPA extractable) iron in soil of North Saurashtra Agro-climatic zone.

district (Table 2).

Delineation of the extent of available iron status in soils of North Saurashtra Agro-climatic Zone of Gujarat through concept of nutrient index

Classification of samples and nutrient index values of different district falls in jurisdiction of North Saurashtra Agro-climatic Zone are given in Table 3 and also depicted graphically in Fig. 3 for available iron. Overall, the soils of Northern Saurashtra Agro-climatic Zone had nutrient index values of 1.79 for available iron. About 31 per cent samples were tested as low class (< 5 mg/kg), 59 per cent samples were under medium class (5-10 mg/kg)

Table 3 : District wise percent distribution of soil samples in low, medium and high fertility classes for available iron.

S. no.	Name of districts	Low	Medium	High	Total sample	Nutrient index	Nutrient index class
1	**Rajkot**	37(30)	59(47)	04(03)	100(80)	1.66	Low
2	**Amreli**	28(23)	59(47)	13(10)	100(80)	1.84	Medium
3	**Surendranagar**	30(30)	48(48)	22(22)	100(100)	1.92	Medium
4	**Jamnagar**	19(11)	73(44)	08(05)	100(60)	1.90	Medium
5	**Devbhumi-Dwarka**	42(17)	45(18)	13(05)	100(40)	1.70	Medium
6	**Morbi**	50(25)	50(25)	0.0(0.0)	100(50)	1.50	Low
7	**Bhavnagar**	20(14)	76(53)	04(03)	100(70)	1.84	Medium
8	**Overall NSAZ**	**31(150)**	**59(282)**	**10(48)**	**100(480)**	**1.79**	**Medium**

Note: Values in parenthesis are indicated number of soil samples.

Table 4 : Correlation matrix among different fractions of iron and soil chemical properties.

Iron	AF-Fe	WSF-Fe	EF-Fe	RF- Fe	Total-Fe	$pH_{2.5}$	$EC_{2.5}$
AF-Fe	1.0						
WSF-Fe	0.375^{**}						
EF-Fe	0.836^{**}	0.458^{**}					
RF- Fe	0.894^{**}	0.537^{**}	0.856^{**}				
Total Fe	0.572^{**}	0.230^{**}	0.438^{**}	0.480^{**}			
$pH_{2.5}$	0.014^{NS}	0.053^{NS}	-0.019^{NS}	0.000^{NS}	0.219^{**}		
$EC_{2.5}$	0.039^{NS}	-0.023^{NS}	0.135^{**}	0.054^{NS}	0.025^{NS}	-0.125^{**}	1.0

*= 5 % level of significance ** = 1 % level of significance.

in different soil group of Saurashtra. Behera and Singh (2010) for maize-wheat cropping sequence in alkaline soils of IARI found the range of total iron 2.36 to 2.61%.

Residual iron ranged from 9084-92622 mg/kg with a mean value of 36134 mg/kg. The highest value of residual ironwas recorded in Surendranagar with a mean of 38702 mg/kg, whereas the lowest value of 32699 mg/kg was recorded in the soil sample collected from Rajkot soils. The overall range of percent available iron in North Saurashtra Agro-climatic was 0.011-0.081% with mean value of 0.026%. The data revealed that the lowest mean value of percent available iron (0.032%) was obtained from samples of Rajkot district and the highest mean value (0.032%) was found in samples of Bhavnagar and 10 per cent sample falls in high available iron class (> 10 mg/kg). The high nutrient index values not found in Northern Saurashtra Agro-climatic districts, while in case of medium vale of nutrient index were found in Amreli, Surendranagar, Jamnagar, Devbhumi-Dwarka, Morbi, and Bhavnagar with value of 1.84, 1.92, 1.90, 1.70, 1.50 and 1.84, respectively. Low nutrient index values of 1.66 was recorded for available iron in the soils of Rajkot.

Correlation between different fractious of iron and soil chemical properties

Iron transformation and its availability in the soils is dependent on its various forms and some soil chemical properties *i.e.* soil pH and EC, therefore, interrelationships

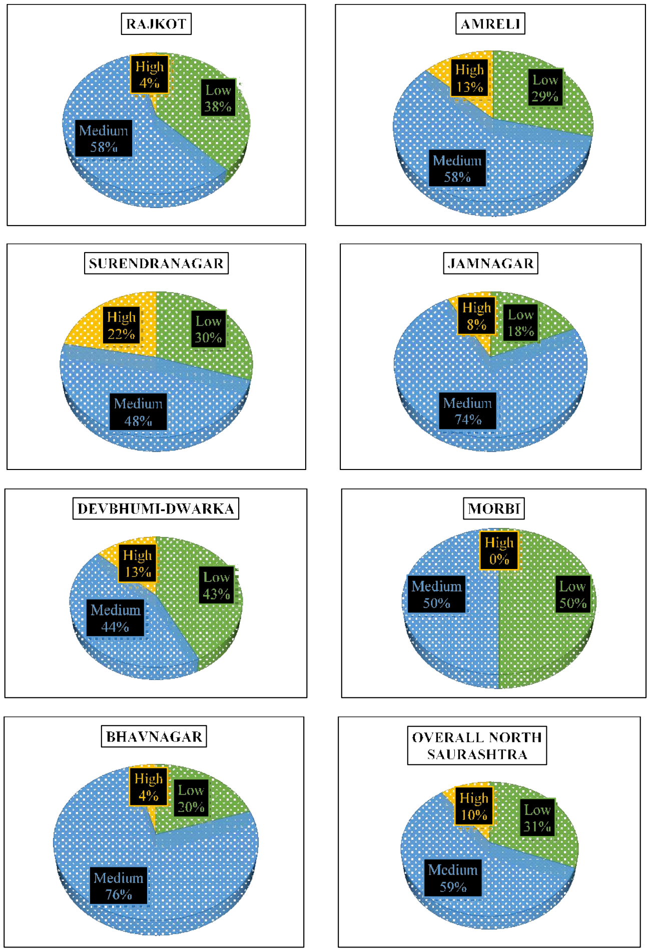

Fig. 3 : District wise percentage of soil samples falling in low, medium and high fertility classes for available iron.

among various forms of iron and soil chemical properties *i.e.* Water soluble iron, Exchangeable iron, Available iron, Reducible iron, Total iron, soil pH and soil EC were worked out. Thus, various soils exhibited varied relationship with available iron with respect to different forms might be depending on the nature of the soil chemical and physical properties.

The data on correlation values indicated highly significant positive relation between available iron with water soluble (r = 0.375**), exchangeable iron (r = 0.836**), reducible (r = 894**) and total (r = 0.572**). These indicated that availability iron increased with increasing the value of water soluble iron, exchangeable iron, reducible iron and total iron, while in case of soil chemical properties like soil $pH_{2.5}$ and $EC_{2.5}$ on different fractions of iron, majorly non-significant and negative correlation might be due to at high range of soil pH (Alkaline) cationic micronutrients has less solubility and availability. The availability of iron was also affected by lime and soil EC. The available iron was highly significant with exchangeable iron and water soluble iron. The

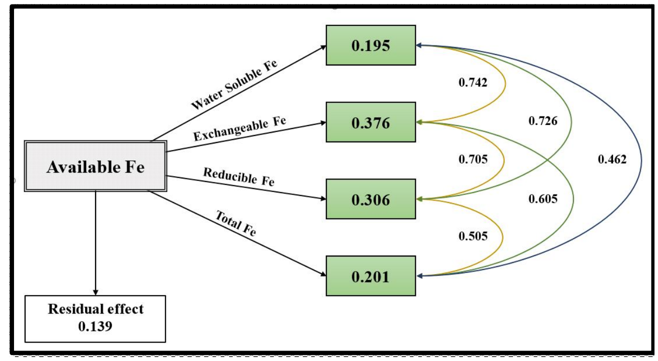

Fig. 4 : Path diagram depicting correlation and direct effects of various fractions of micronutrients on available iron.

percent investigations find supports from the works reported earlier by Pati and Mukhopadhyay (2011), Young *et al.* (2006) and Joshi *et al.* (2017).

Regression analysis and multiple regression co-efficient of available iron with different fractions of iron and soil chemical properties

Many workers have tried to correlated water soluble, exchangeable, reducible and total fractions with available fractions of iron and if this association is significant then regression equation is worked out. Such equations are very useful in characterization of a large number of samples. The highly significant correlation coefficient (r) value were obtained between available iron with water soluble, exchangeable, reducible as well as total of micronutrients. The available iron regression with other fractions explained up to 86.32 of the variation in soils of North Saurashtra Agro-climatic Zone. The result also supported by Yasrebi *et al.* (1994), Prasad *et al.* (1995) and Ramzan *et al.* (2014).

Regression equations for available of iron based on different fractions and soil chemical properties

Dependent variables	Regression Equation ($Y= a +b_1x_1 +b_2x_2$……..)	R square
Av Fe (Y)	Y= -3.039+1.15 (Water Soluble Fe) + 1.13 (Exchangeable Fe) + 3.63 (Reducible Fe) + 0.0 (Total Fe) + 0.376 (Soil $pH_{2.5}$) + 0.114 (Soil $EC_{2.5}$)	0.863

Path co-efficient analysis between different fractions of ironin soils

From the path analysis of different fractions of iron in soils of North Saurashtra Agro-climatic Zone presented in Fig. 4, it can conclude that exchangeable iron ascribed maximum direct positive effect on available iron followed by reducible iron (0.306), exchangeable (0.376) total iron (0.201) and water soluble iron (0.195).

Conclusion

Based on analysis data of collected 480 soil samples, soil fertility status of available iron was medium (59%). Further, analysed data of iron factions like water soluble, exchangeable, available, reducible, available total, total, residual and percent available were noted in mean value of 0642, 2.04, 6.26, 0.101, 9.94, 3614, 36134 mg/kg and 0.026%, respectively. The available Fe was highly significantly positive correlated towards to their respective fractions, but those were remain unaffected by soil chemical properties like $pH_{2.5}$ and $EC_{2.5}$. Based on multiple correlations and regression analysis, the percent variance (R^2) of available Fe was note in value of 0.863. As per the path analysis of available iron with their fractions, the direct positive effects were found on the availability of iron by their respective fractions. Among the different fractions of iron, relatively higher direct positive effectswas found on availability of iron by their exchangeable fraction.

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